Studying low-mass stars in the VO…
and other things! (yet another change of title)

Amelia Bayo (transiting from MPIA to Valparaiso)

Disclaimer: Blames are more likely on me…
good ideas, if any, most likely coming from Enrique Solano or Carlos Rodrigo

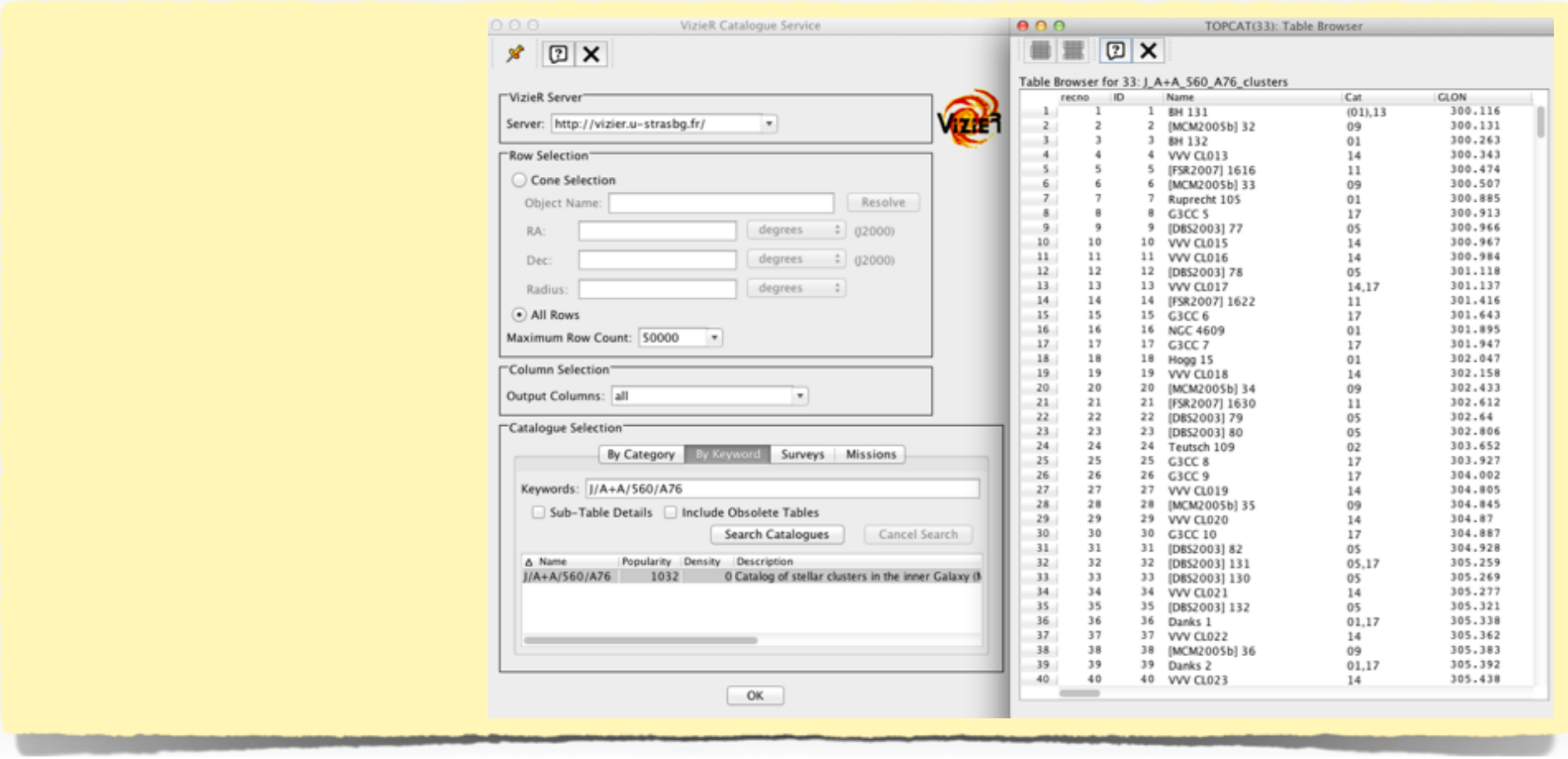

Outline

From a hybrid-user perspective (very biased, and not pretending AT ALL to be complete):

- What kind of science cases have benefited HUGELY from the VO initiative?
- Where is ample room for improvement?
- Could I make some suggestions?

The happy endings…

- Data related:
  - CDS wonders vs pain of getting, for example, ApJS IOP tables



The happy endings…

- Data related:
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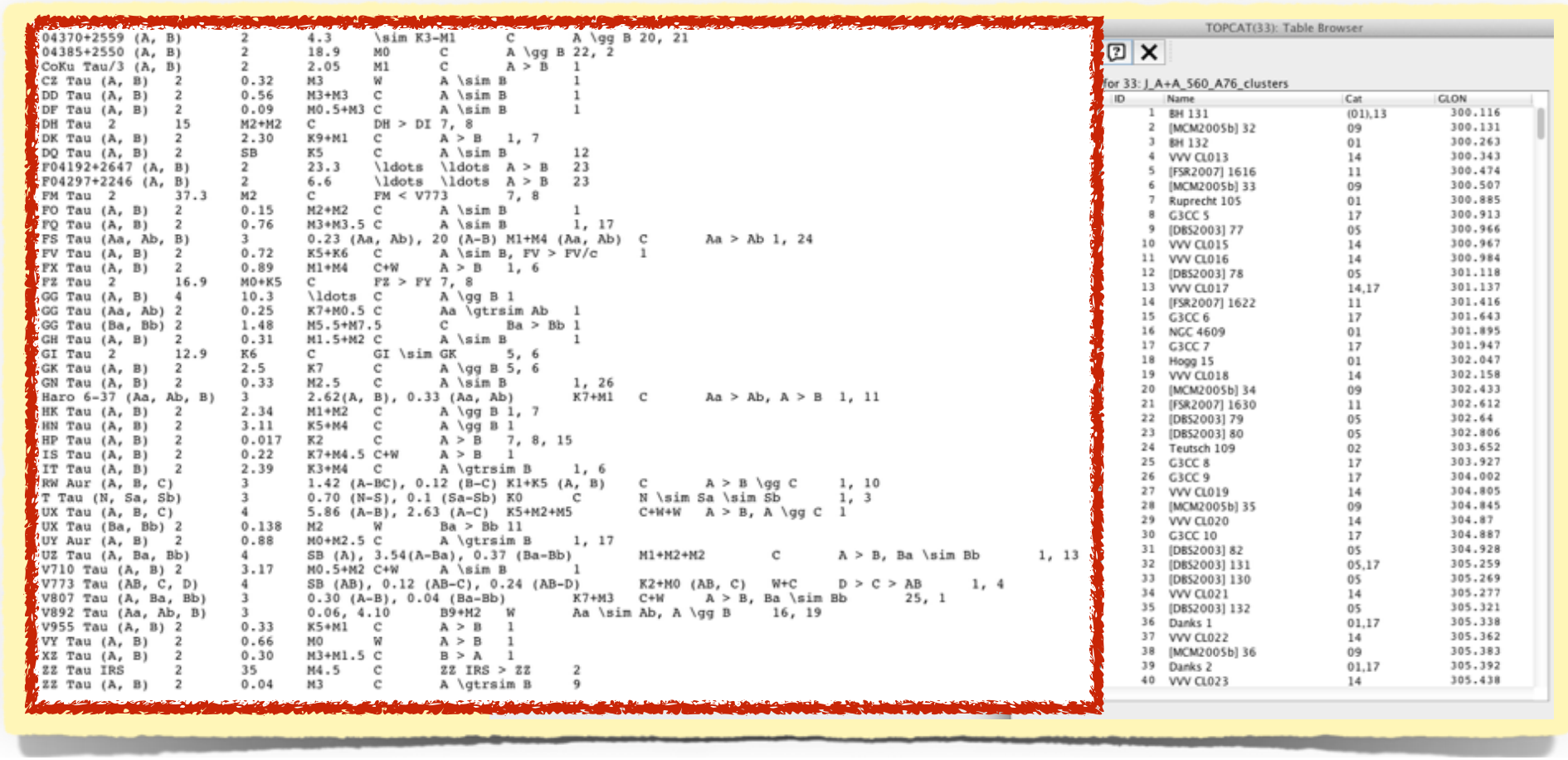


04370+2559 (A, B)	2	4.3	\sim K3-M1	C	A \gg B 20, 21	
04385+2550 (A, B)	2	18.9	M0	C	A \gg B 22, 2	
CoKu Tau/3 (A, B)	2	2.05	M1	C	A > B 1	
CZ Tau (A, B)	2	0.32	M3	W	A \sim B 1	
DD Tau (A, B)	2	0.56	M3+M3	C	A \sim B 1	
DF Tau (A, B)	2	0.09	M0.5+M3	C	A \sim B 1	
DH Tau 2	15	M2+M2	C	DH > DI 7, 8		
DK Tau (A, B)	2	2.30	K9+M1	C	A > B 1, 7	
DQ Tau (A, B)	2	SB	K5	C	A \sim B 12	
F04192+2647 (A, B)	2	23.3	\ldots	\ldots	A > B 23	
F04297+2246 (A, B)	2	6.6	\ldots	\ldots	A > B 23	
FM Tau 2	37.3	M2	C	FM < V773	7, 8	
FO Tau (A, B)	2	0.15	M2+M2	C	A \sim B 1	
FQ Tau (A, B)	2	0.76	M3+M3.5	C	A \sim B 1, 17	
FS Tau (Aa, Ab, B)	3	0.23 (Aa, Ab), 20 (A-B)	M1+M4 (Aa, Ab)	C	Aa > Ab 1, 24	
FV Tau (A, B)	2	0.72	K5+K6	C	A \sim B, FV > FV/c 1	
FX Tau (A, B)	2	0.89	M1+M4	C+W	A > B 1, 6	
FZ Tau 2	16.9	M0+K5	C	FZ > FY 7, 8		
GG Tau (A, B)	4	10.3	\ldots	C	A \gg B 1	
GG Tau (Aa, Ab)	2	0.25	K7+M0.5	C	Aa \gtrsim Ab 1	
GG Tau (Ba, Bb)	2	1.48	M5.5+M7.5	C	Ba > Bb 1	
GH Tau (A, B)	2	0.31	M1.5+M2	C	A \sim B 1	
GI Tau 2	12.9	K6	C	GI \sim GK 5, 6		
GK Tau (A, B)	2	2.5	K7	C	A \gg B 5, 6	
GN Tau (A, B)	2	0.33	M2.5	C	A \sim B 1, 26	
Haro 6-37 (Aa, Ab, B)	3	2.62(A, B), 0.33 (Aa, Ab)		K7+M1	C	Aa > Ab, A > B 1, 11
HK Tau (A, B)	2	2.34	M1+M2	C	A \gg B 1, 7	
HN Tau (A, B)	2	3.11	K5+M4	C	A \gg B 1	
HP Tau (A, B)	2	0.017	K2	C	A > B 7, 8, 15	
IS Tau (A, B)	2	0.22	K7+M4.5	C+W	A > B 1	
IT Tau (A, B)	2	2.39	K3+M4	C	A \gtrsim B 1, 6	
RW Aur (A, B, C)	3	1.42 (A-BC), 0.12 (B-C)	K1+K5 (A, B)	C	A > B \gg C 1, 10	
T Tau (N, Sa, Sb)	3	0.70 (N-S), 0.1 (Sa-Sb)	K0	C	N \sim Sa \sim Sb 1, 3	
UX Tau (A, B, C)	4	5.86 (A-B), 2.63 (A-C)	K5+M2+M5		C+W+W A > B, A \gg C 1	
UX Tau (Ba, Bb)	2	0.138	M2	W	Ba > Bb 11	
UY Aur (A, B)	2	0.88	M0+M2.5	C	A \gtrsim B 1, 17	
UZ Tau (A, Ba, Bb)	4	SB (A), 3.54(A-Ba), 0.37 (Ba-Bb)		M1+M2+M2	C	A > B, Ba \sim Bb 1, 13
V710 Tau (A, B)	2	3.17	M0.5+M2	C+W	A \sim B 1	
V773 Tau (AB, C, D)	4	SB (AB), 0.12 (AB-C), 0.24 (AB-D)		K2+M0 (AB, C)	W+C	D > C > AB 1, 4
V807 Tau (A, Ba, Bb)	3	0.30 (A-B), 0.04 (Ba-Bb)		K7+M3	C+W	A > B, Ba \sim Bb 25, 1
V892 Tau (Aa, Ab, B)	3	0.06, 4.10	B9+M2	W	Aa \sim Ab, A \gg B 16, 19	
V955 Tau (A, B)	2	0.33	K5+M1	C	A > B 1	
VY Tau (A, B)	2	0.66	M0	W	A > B 1	
XZ Tau (A, B)	2	0.30	M3+M1.5	C	B > A 1	
ZZ Tau IRS	2	35	M4.5	C	ZZ IRS > ZZ 2	
ZZ Tau (A, B)	2	0.04	M3	C	A \gtrsim B 9	

TOPCAT(33): Table Browser

for 33: J_A+A_560_A76_clusters

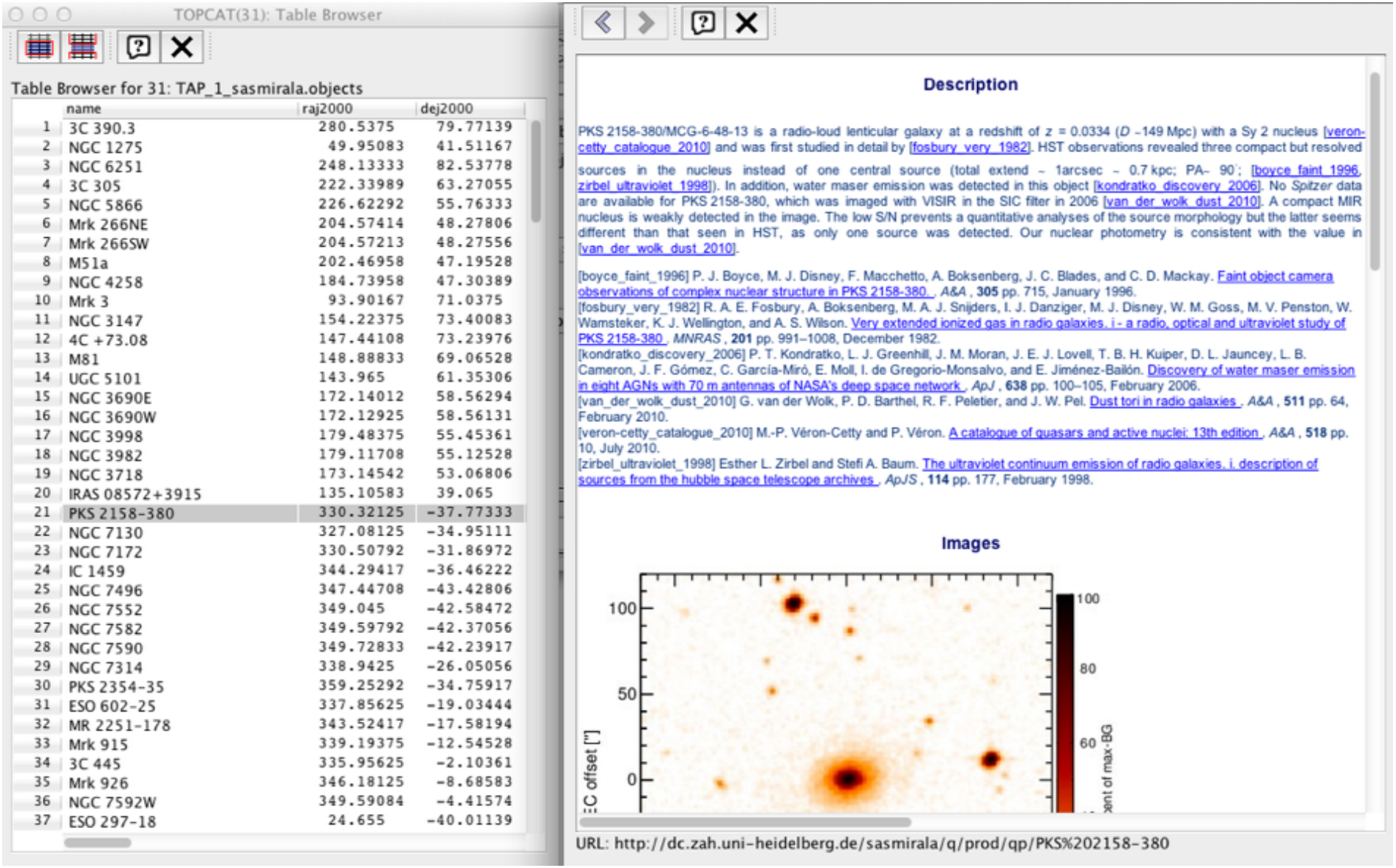
ID	Name	Cat	GLON
1	BH 131	(01),13	300.116
2	[MCM2005b] 32	09	300.131
3	BH 132	01	300.263
4	VVV CL013	14	300.343
5	[FSR2007] 1616	11	300.474
6	[MCM2005b] 33	09	300.507
7	Ruprecht 105	01	300.885
8	G3CC 5	17	300.913
9	[DBS2003] 77	05	300.966
10	VVV CL015	14	300.967
11	VVV CL016	14	300.984
12	[DBS2003] 78	05	301.118
13	VVV CL017	14,17	301.137
14	[FSR2007] 1622	11	301.416
15	G3CC 6	17	301.643
16	NGC 4609	01	301.895
17	G3CC 7	17	301.947
18	Hogg 15	01	302.047
19	VVV CL018	14	302.158
20	[MCM2005b] 34	09	302.433
21	[FSR2007] 1630	11	302.612
22	[DBS2003] 79	05	302.64
23	[DBS2003] 80	05	302.806
24	Teutsch 109	02	303.652
25	G3CC 8	17	303.927
26	G3CC 9	17	304.002
27	VVV CL019	14	304.805
28	[MCM2005b] 35	09	304.845
29	VVV CL020	14	304.87
30	G3CC 10	17	304.887
31	[DBS2003] 82	05	304.928
32	[DBS2003] 131	05,17	305.259
33	[DBS2003] 130	05	305.269
34	VVV CL021	14	305.277
35	[DBS2003] 132	05	305.321
36	Danks 1	01,17	305.338
37	VVV CL022	14	305.362
38	[MCM2005b] 36	09	305.383
39	Danks 2	01,17	305.392
40	VVV CL023	14	305.438

The happy endings…

- Data related:
  - CDS wonders vs pain of getting, for example, IOP tables
  - The “sasmirala” atlas

The happy endings…

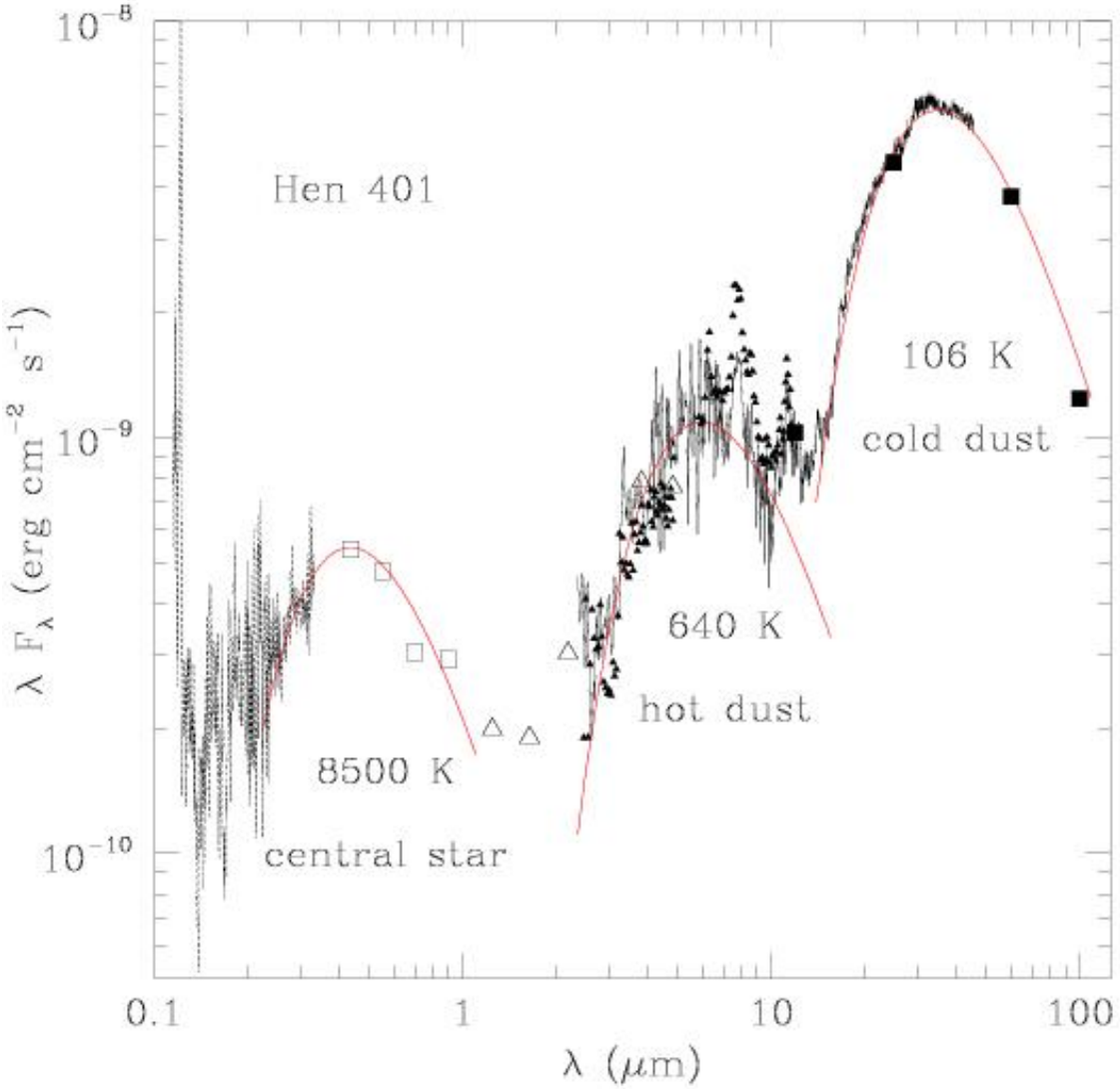
Asmus et al 2014



The happy endings…

- Data related:
    - CDS wonders vs pain of getting, for example, IOP tables
    - The “sasmirala” atlas
- Tool related (development)
    - The final AVO science demo

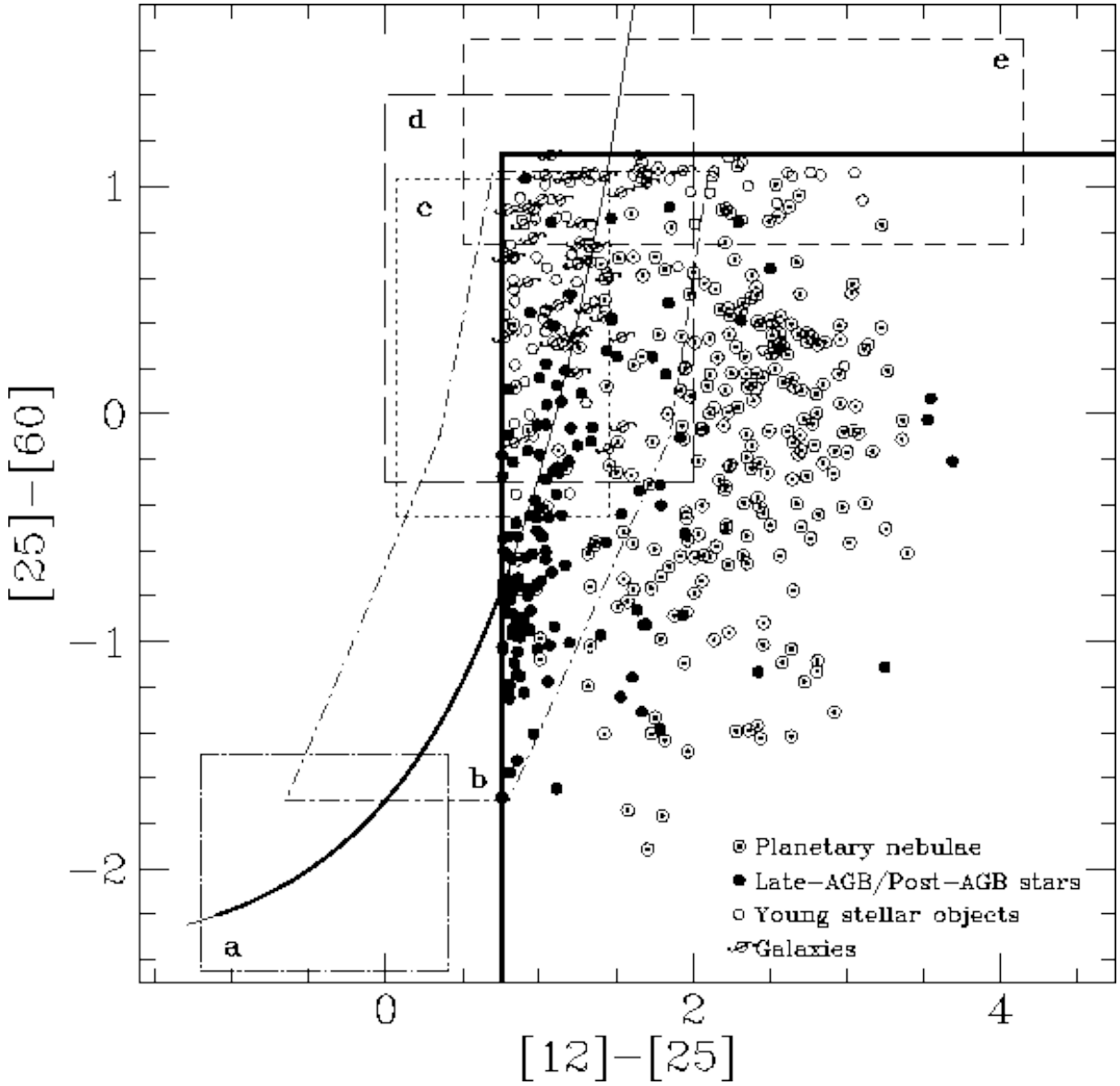
2005 AVO demo: the PPNe case



Transition phase
AGB -> PN

Multiple (and variable) components in their SEDs

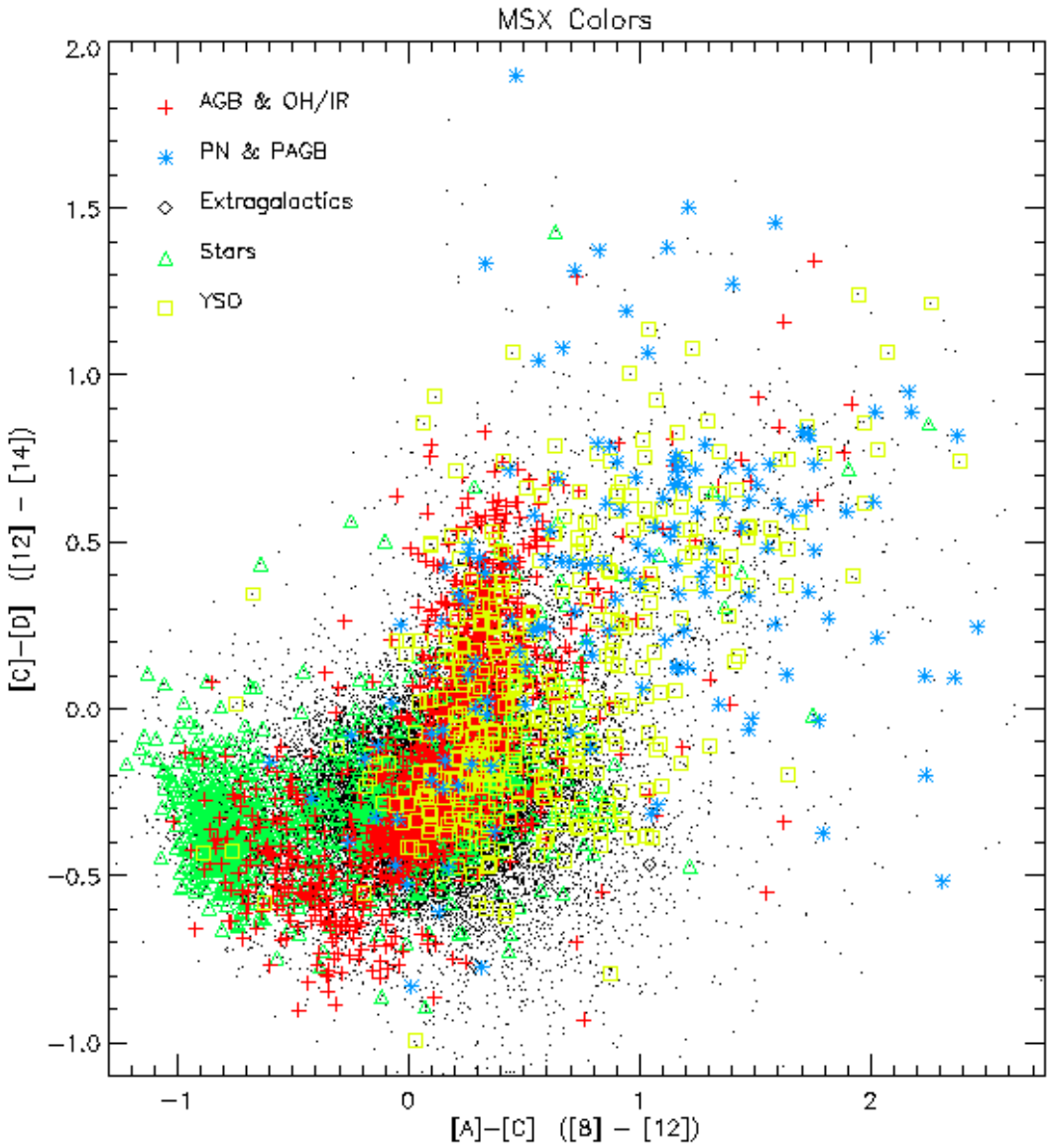
2005 AVO demo: the PPNe case



Distribution of identified sources in the GLMP catalog

Garcia-Lario et al. (1997)

2005 AVO demo: the PPNe case



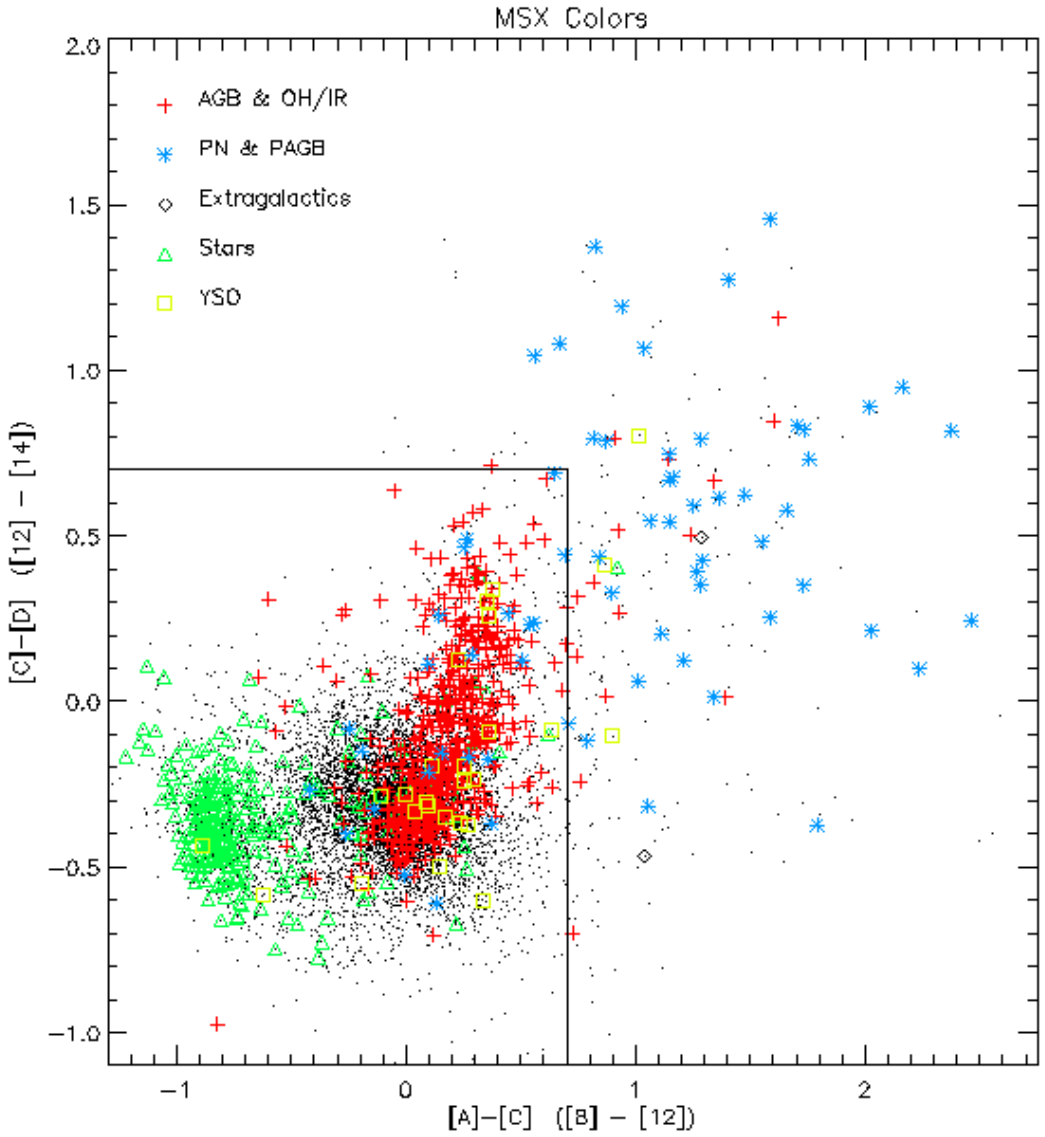
✓17657 sources with good quality MSX photometry 8-14 micron

✓3278 with SIMBAD class.

✓155 known PNe or Post-AGB stars

✓Confusion with other type of sources

2005 AVO demo: the PPNe case



If we harden our selection criteria:

✓|b| ≥ 2 degrees

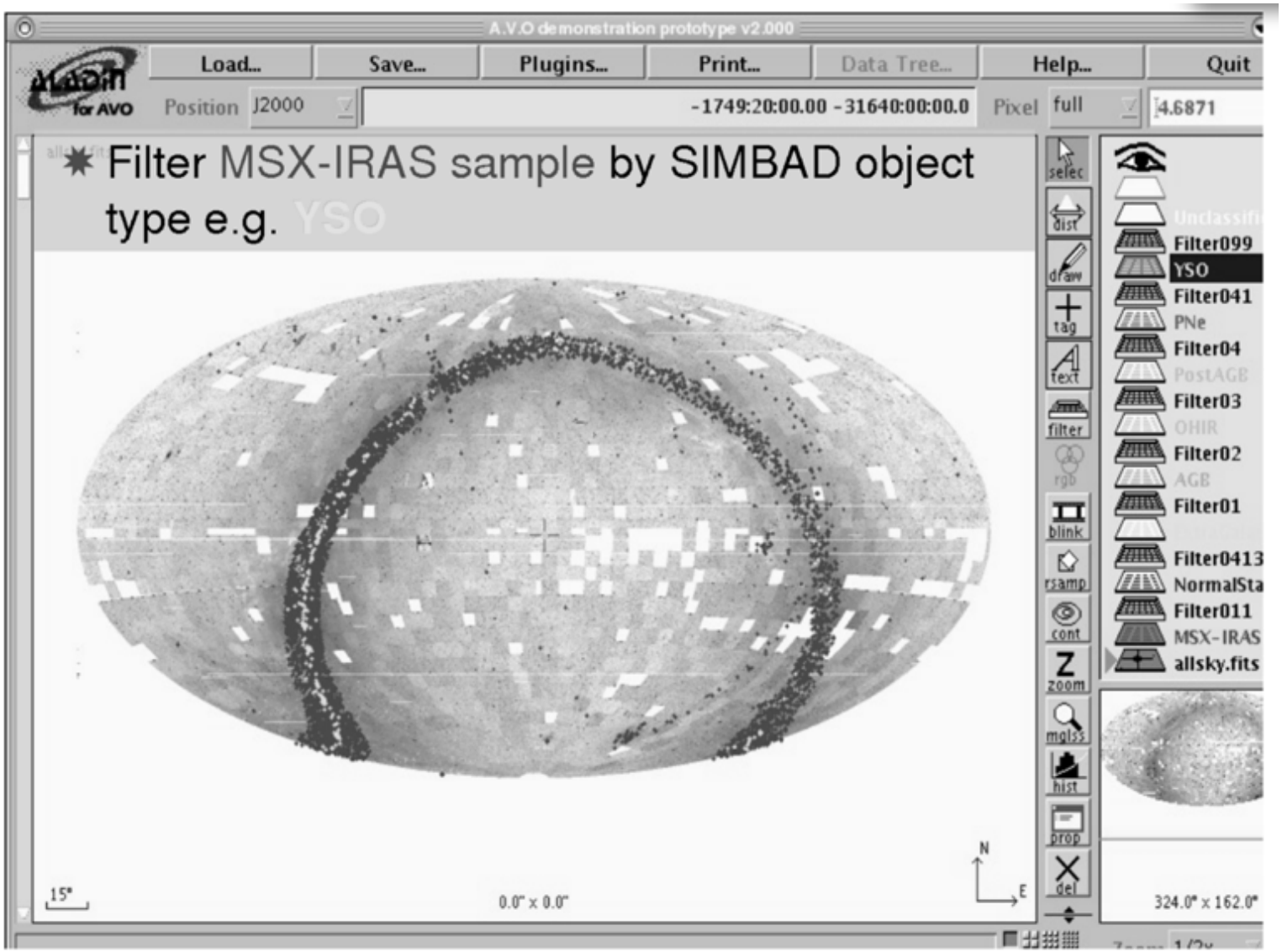
✓[A]-[C] ≥ 0.7

✓[C]-[D] ≥ 0.7

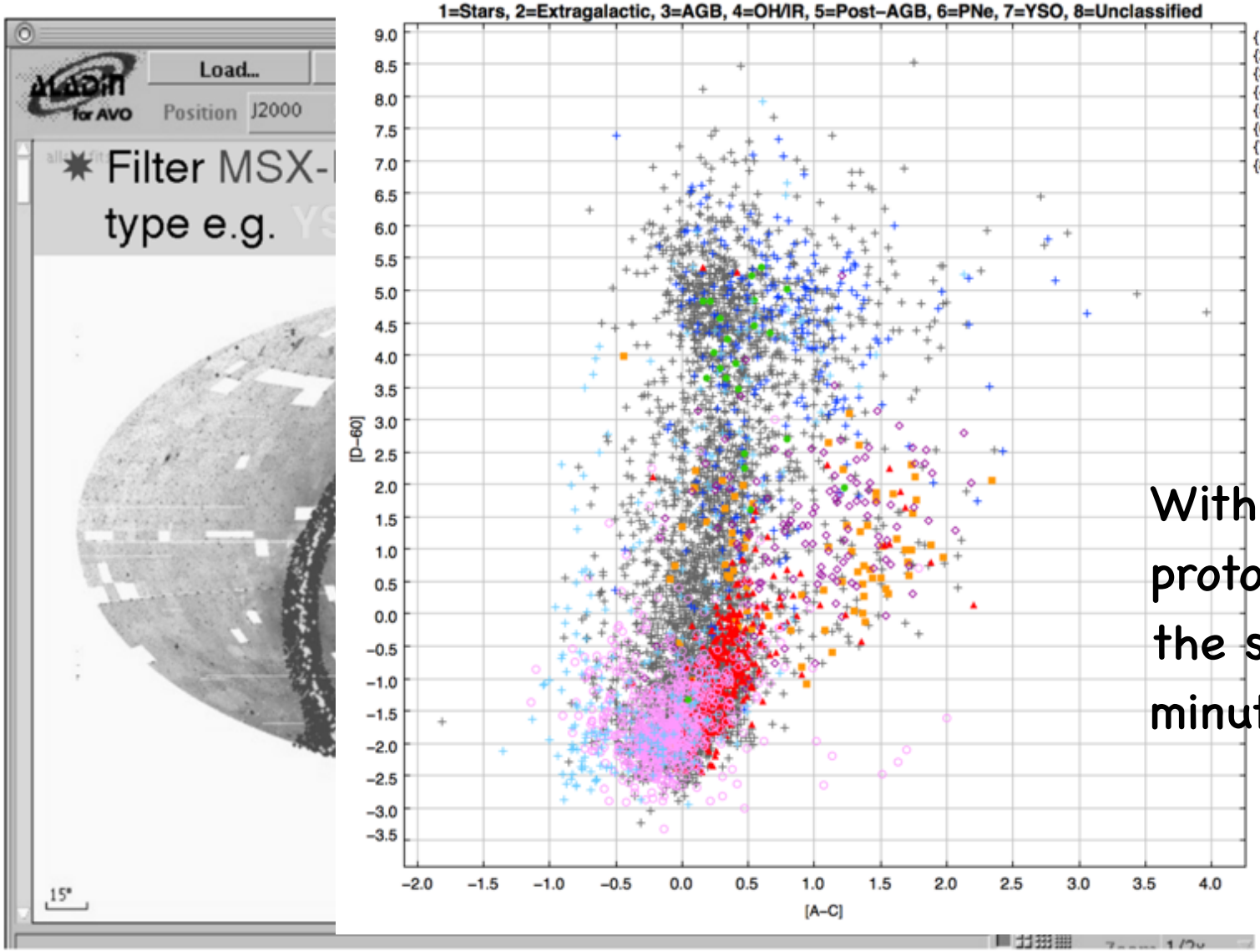
Large majority of PNe and Post-AGB stars...

and many new candidates!

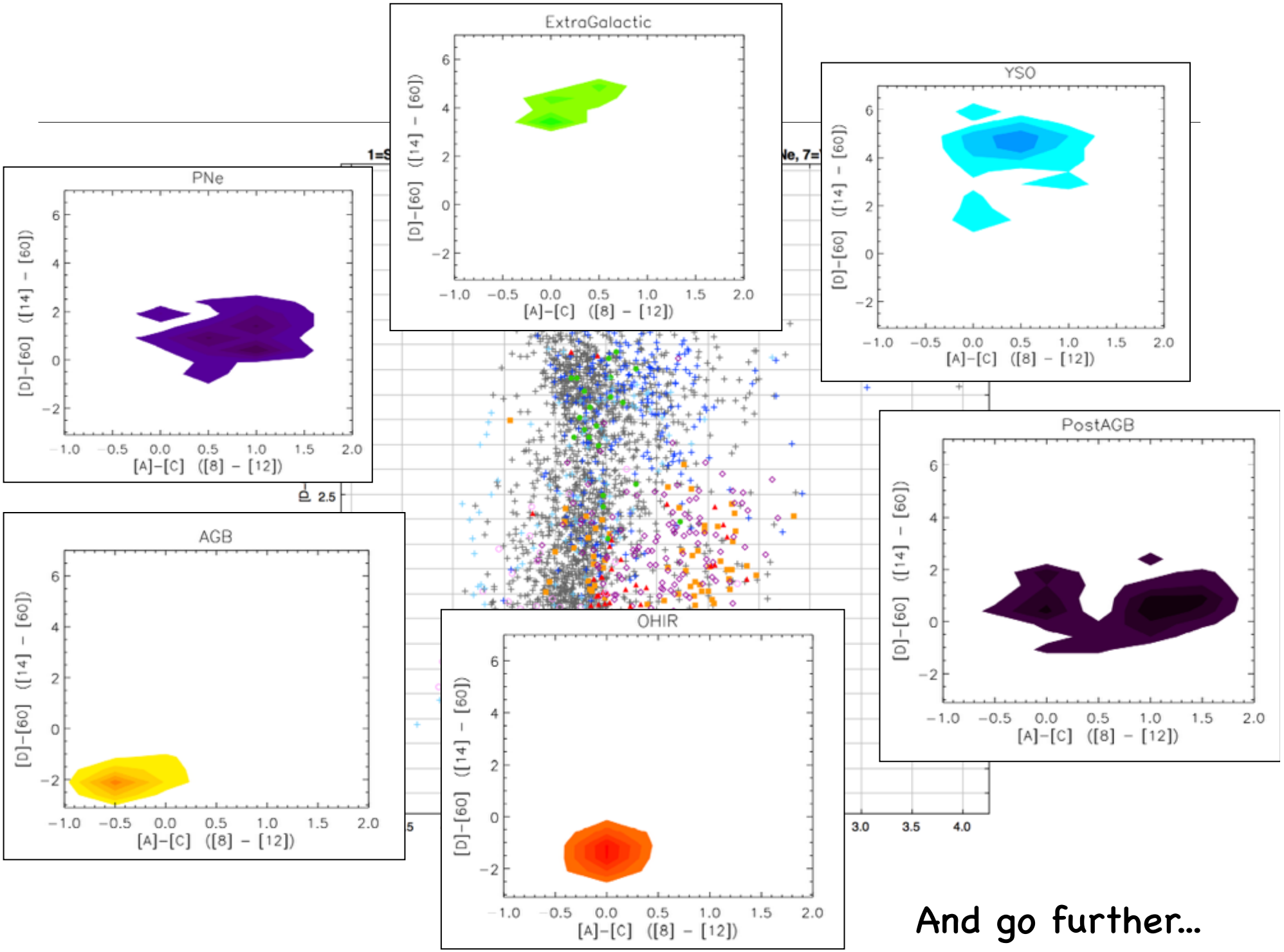
2005 AVO demo: the PPNe case



2005 AVO demo: the PPNe case



With the AVO prototype -> reach the same point in minutes...



And go further...

The happy endings…

- Data related:
  - CDS wonders vs pain of getting, for example, IOP tables
  - The “sasmirala” atlas
- Tool related (development)
  - The final AVO science demo
  - The birth of VOSA (and its continuous development)

Warning! self-promotion

✓ March 2007

Cool objects: From SED fitting to age estimation.

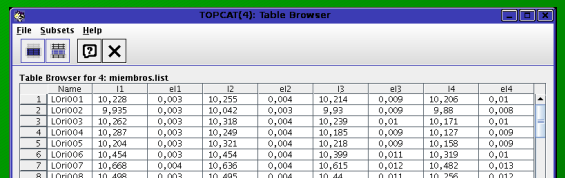
A. Bayo[1], D. Barrado y Navascués[1], M. Morales–Calderón[1], E. Solano[1,2], C. Rodrigo[1,2], R. Gutiérrez[1,2], F. Allard[3]

[1]Laboratorio de Astrofísica Espacial y Física Fundamental (LAEFF-INTA), P.O. 50727, E-28080 Madrid, Spain
[2]Spanish Virtual Observatory, Spain
[3]Centre de Recherche Astronomique de Lyon (CRAL), Ecole Normale Supérieure de Lyon, 69364, Lyon, France

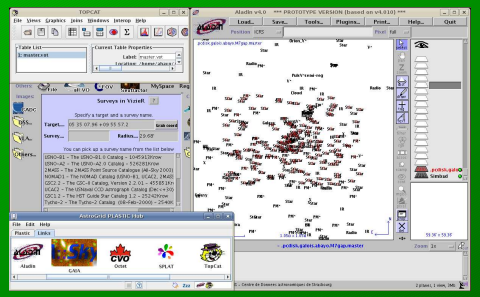
Abstract

One of the typical tools to estimate physical parameters of almost any kind of astronomical object is to perform a fitting of synthetic spectra or photometry extracted from theoretical models to observational data. This process usually involves working with multiwavelength data, which is one of the cornerstones of the VO philosophy. From this kind of studies, when combining with theoretical isochrones one can even estimate ranges of ages. We present the results from a code designed to perform χ^2 tests following two different methodologies to fit observational data: using grids of models (on their synthetic photometry), and combinations of blackbodies (including modified blackbodies). In particular, we use the models by the Lyon group. Some steps in this process can already be done in a VO enviroment, and the rest are in the process of development. We must note that this kind of surveys in star forming regions, clusters, etc. produce a huge amount of data, very tedious to analyse using the traditional methodology. Therefore this is an ideal example of the VO capabilities.

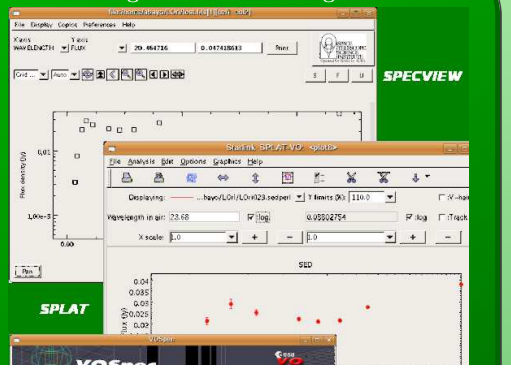
Starting point:
Your own data (photometry or spectra)



Searching "non-spectroscopic" data:



Building the multiwavelength SEDs



Warning! self-promotion

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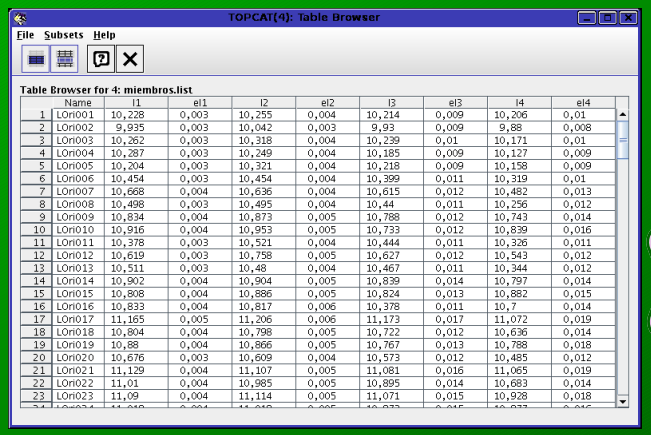
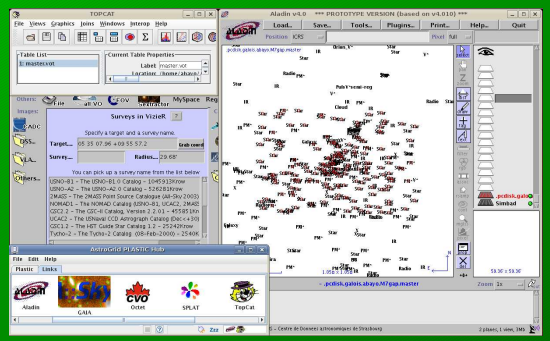


	Name	I1	el1	I2	el2	I3	el3	I4	el4
1	LOri001	10,228	0,003	10,255	0,004	10,214	0,009	10,206	0,01
2	LOri002	9,935	0,003	10,042	0,003	9,93	0,009	9,88	0,008
3	LOri003	10,262	0,003	10,318	0,004	10,239	0,01	10,171	0,01
4	LOri004	10,287	0,003	10,249	0,004	10,185	0,009	10,127	0,009
5	LOri005	10,204	0,003	10,321	0,004	10,218	0,009	10,158	0,009
6	LOri006	10,454	0,003	10,454	0,004	10,399	0,011	10,319	0,01
7	LOri007	10,668	0,004	10,636	0,004	10,615	0,012	10,482	0,013
8	LOri008	10,498	0,003	10,495	0,004	10,44	0,011	10,256	0,012
9	LOri009	10,834	0,004	10,873	0,005	10,788	0,012	10,743	0,014
10	LOri010	10,916	0,004	10,953	0,005	10,733	0,012	10,839	0,016
11	LOri011	10,378	0,003	10,521	0,004	10,444	0,011	10,326	0,011
12	LOri012	10,619	0,003	10,758	0,005	10,627	0,012	10,543	0,012
13	LOri013	10,511	0,003	10,48	0,004	10,467	0,011	10,344	0,012
14	LOri014	10,902	0,004	10,904	0,005	10,839	0,014	10,797	0,014
15	LOri015	10,808	0,004	10,886	0,005	10,824	0,013	10,882	0,015
16	LOri016	10,833	0,004	10,817	0,006	10,378	0,011	10,7	0,014
17	LOri017	11,165	0,005	11,206	0,006	11,173	0,017	11,072	0,019
18	LOri018	10,804	0,004	10,798	0,005	10,722	0,012	10,636	0,014
19	LOri019	10,88	0,004	10,866	0,005	10,767	0,013	10,788	0,018
20	LOri020	10,676	0,003	10,609	0,004	10,573	0,012	10,485	0,012
21	LOri021	11,129	0,004	11,107	0,005	11,081	0,016	11,065	0,019
22	LOri022	11,01	0,004	10,985	0,005	10,895	0,014	10,683	0,014
23	LOri023	11,09	0,004	11,114	0,005	11,071	0,015	10,928	0,018

Photometric data in four bands.

Searching "non-spectroscopic" data:

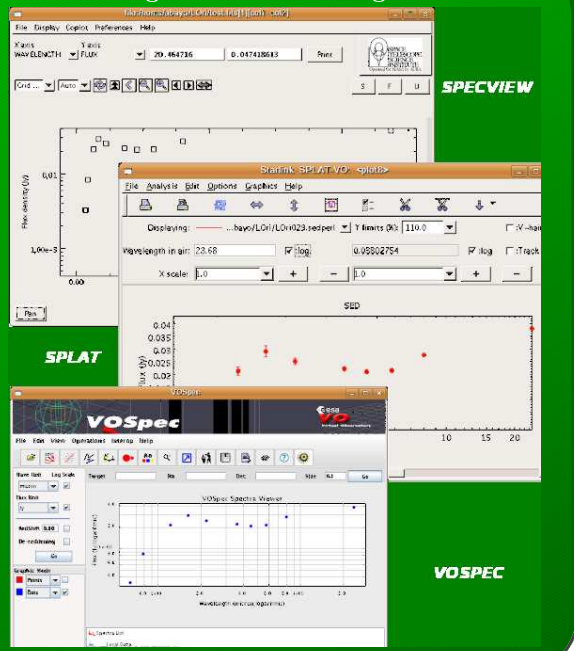


Photometric catalogues, radial velocities measurements, Simbad classification, ...

Searching spectroscopic data:
via batch mode query to VOSED.

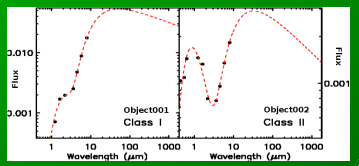
```
wget --save-cookies cookies.txt --load-cookies cookies.txt --keep-session-cookies
    http://sdc.laeff.inta.es/vosed/jsp/form_search.jsp
wget --save-cookies cookies.txt --load-cookies cookies.txt --keep-session-cookies
    http://sdc.laeff.inta.es/vosed/jsp/res_search.jsp?obj_id=&ra=83.446596&de=9.9273633
    &rad=0.01&ssap_services=all&src_uvbybeta=0&src_2mass=0&src_hip=0&teo_dalessio=on&submit
    =Submit+Query
wget --save-cookies cookies.txt --load-cookies cookies.txt --keep-session-cookies
    http://sdc.laeff.inta.es/vosed/jsp/res_search.jsp?submitGetData=Retrieve+Marked+Data
    &filas_ssap=all&filas_stromgren=0&filas_2mass=0 -O object1.zip
```

Building the multiwavelength SEDs



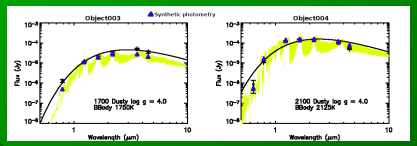
Warning! self-promotion

Blackbody fittings (combinations, modified by different β)

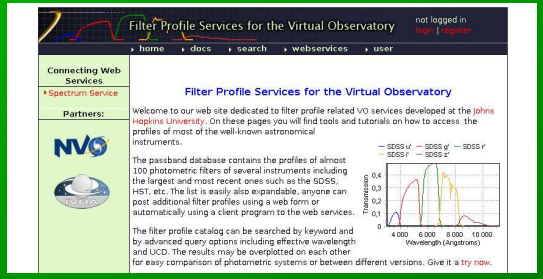


Under development

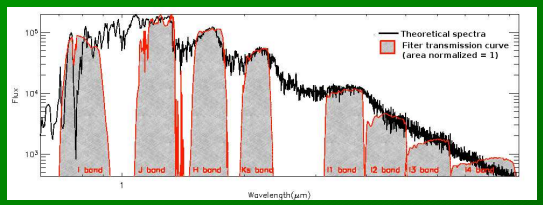
Synthetic photometry fittings



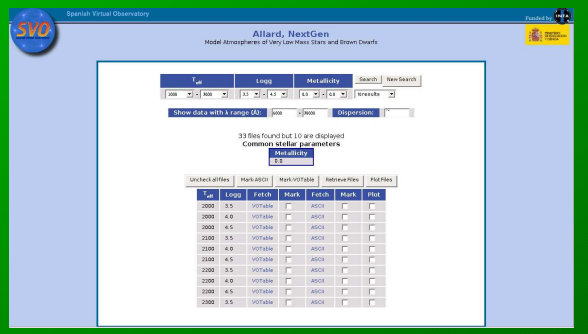
Filter selection.



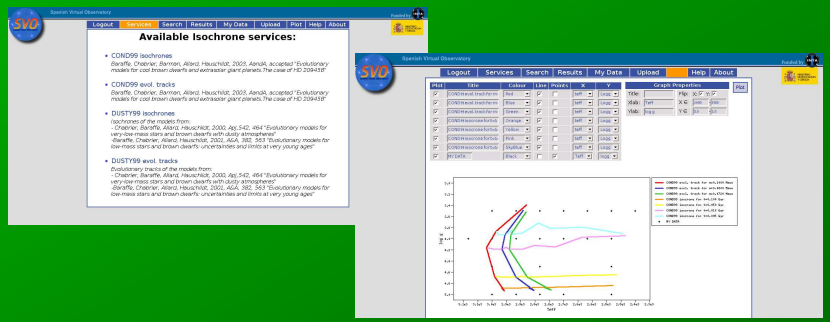
Filter+Synthetic spectra = Synthetic photometry.



Obtaining synthetic spectra.



Comparison with theoretical isochrones and evolutionary tracks.

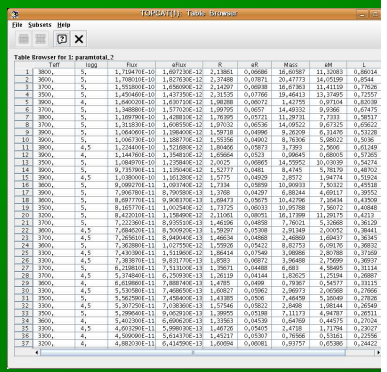


Estimation of physical parameters.

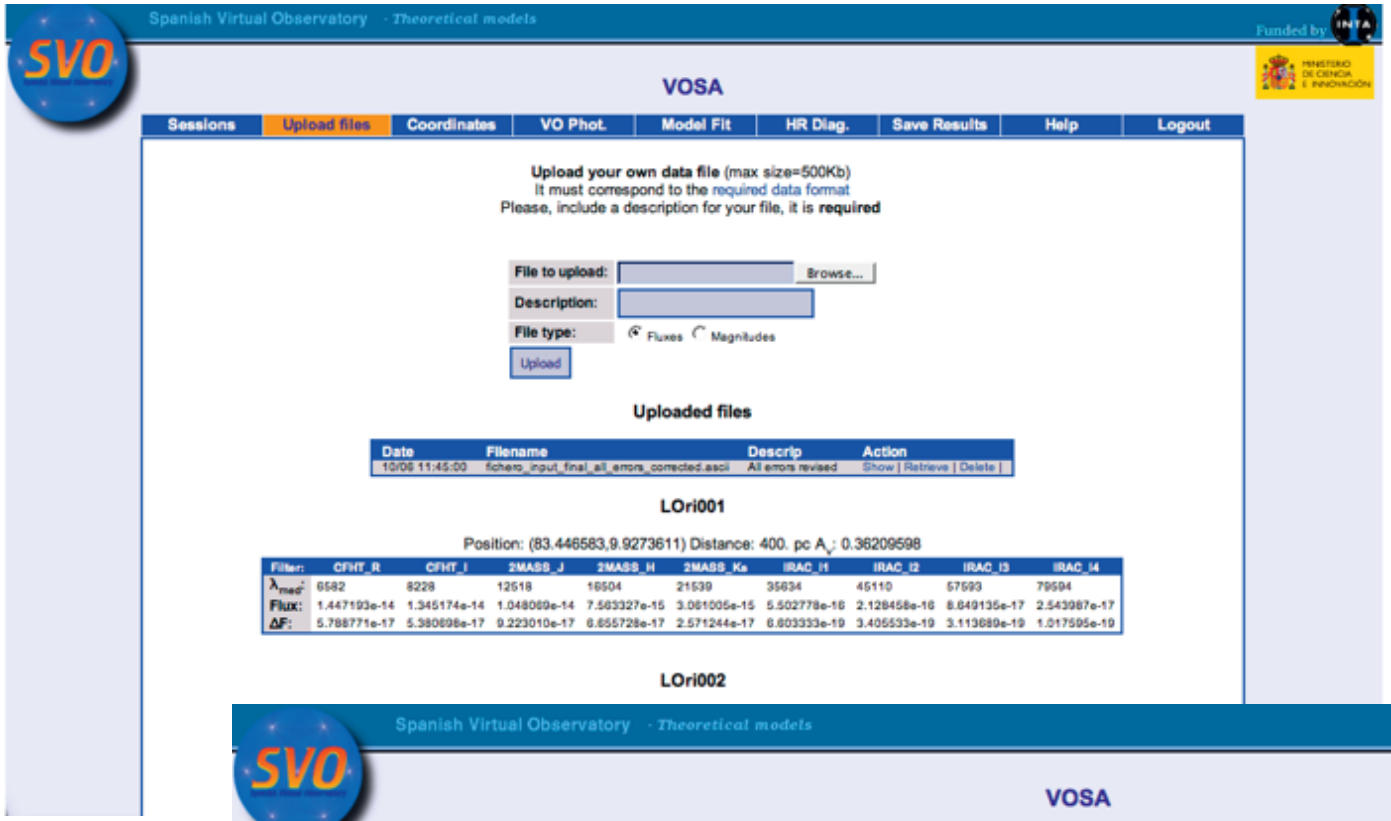
$$\log g = 4.44 + \log M(M_\odot) - 2\log R(R_\odot)$$

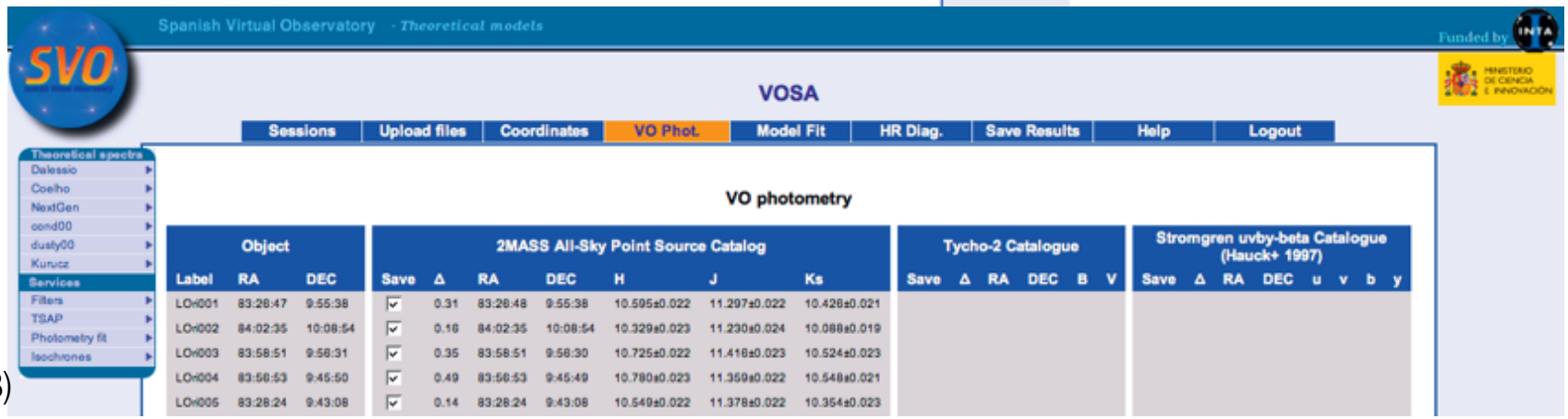
$$d(\mathrm{pc}) = 2.26 \times 10^{-8} R_*(R_\odot) \sqrt{\left(\frac{\mathrm{F_{Model}}}{\mathrm{F_{Obs}}}\right)}$$

$$\mathrm{F_{Obs}} = \left(\frac{MG}{gd}\right)^2 \sigma \mathrm{T_{eff}}^4$$



And VOSA came to life!





Bayo et al. (2008)

And VOSA came to life!

Spanish Virtual Observatory · *Theoretical models*

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VOSA

Sessions | Upload files | Coordinates | VO Phot. | Model Fit | HR Diag. | Save Results | Help | Logout

Upload your own data file (max size=500Kb)
It must correspond to the required data format
Please, include a description for your file, it is **required**

File to upload: Browse...
Description:
File type: Fluxes Magnitudes
Upload

Uploaded files

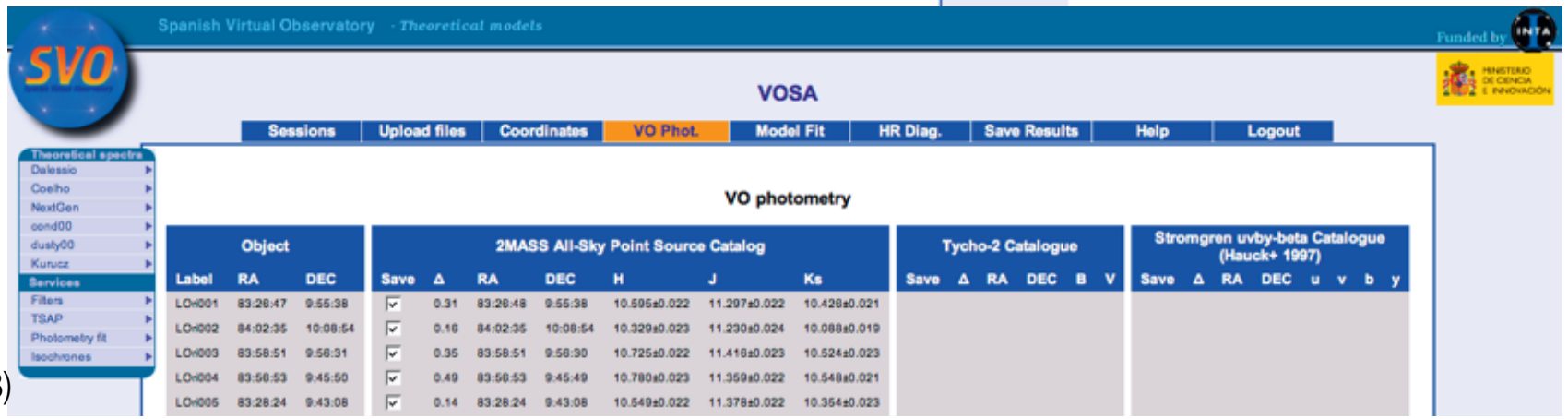
Date	Filename	Descrip	Action
10/06 11:45:00	fichero_input_final_all_errors_corrected.ascii	All errors revised	Show | Retrieve | Delete |

LOri001

Position: (83.446583,9.9273611) Distance: 400. pc A_v: 0.36209598

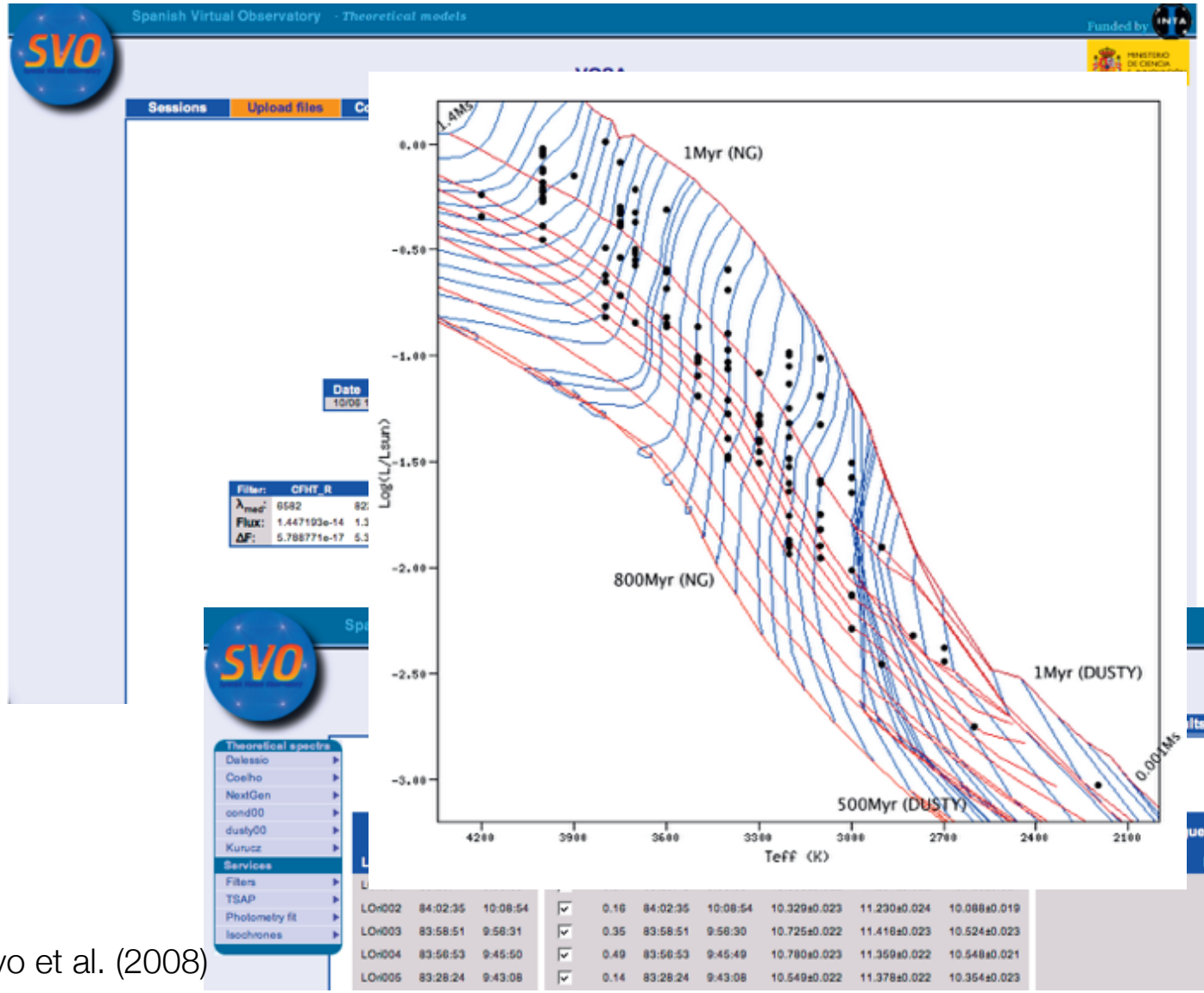
Filter:	CFHT_R	CFHT_I	2MASS_J	2MASS_H	2MASS_Ks	IRAC_I1	IRAC_I2	IRAC_I3	IRAC_I4
λ_{mod}:	6582	8228	12518	16504	21539	35634	45110	57593	79594
Flux:	1.447193e-14	1.345174e-14	1.048069e-14	7.583327e-15	3.061005e-15	5.502778e-16	2.128458e-16	8.649135e-17	2.543987e-17
ΔF:	5.788771e-17	5.380698e-17	9.223010e-17	6.655728e-17	2.571244e-17	6.603333e-19	3.405533e-19	3.113689e-19	1.017595e-19

LOri002



Bayo et al. (2008)

And VOSA came to life!

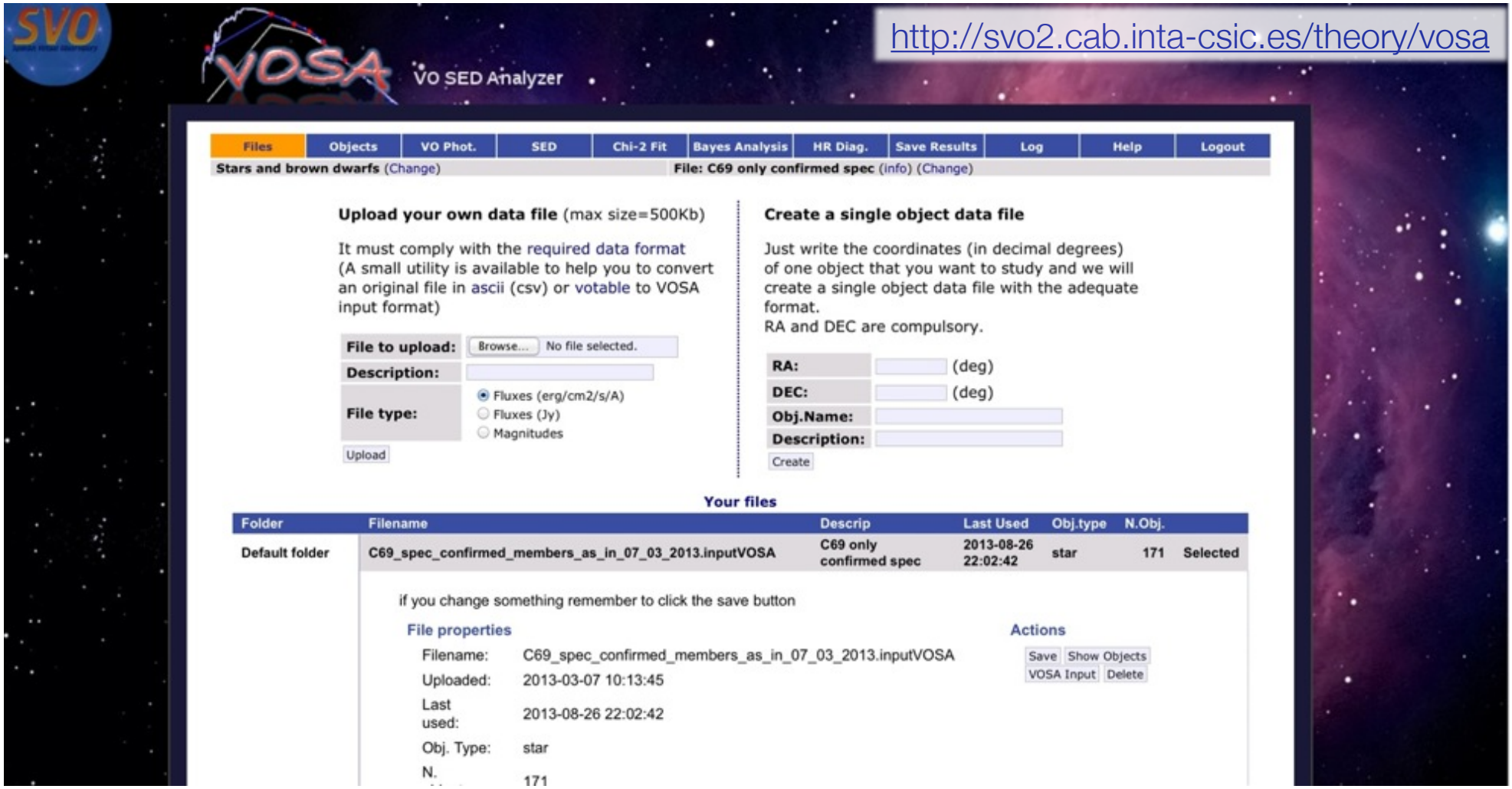


Bayo et al. (2008)

And there was room for improvement

- “Limited to” / “conceived for” stars and brown dwarfs, what about older sources? and more massive? and ~~science-fiction~~ uhmm extragalactic studies?
- Reflected in the available collections of models: Kurucz, NextGen, COND, DUSTY and not many more
- Brute force fitting but no study of the relevance of the individual parameters to the fit
- No A_V estimation
- Not design to work with a single object (input format)
- Variety of catalogs offered but you can always do better and also look for more than photometry
- No Isochrone interpolation, make it even more VO!
- Anything else in the wish-list?

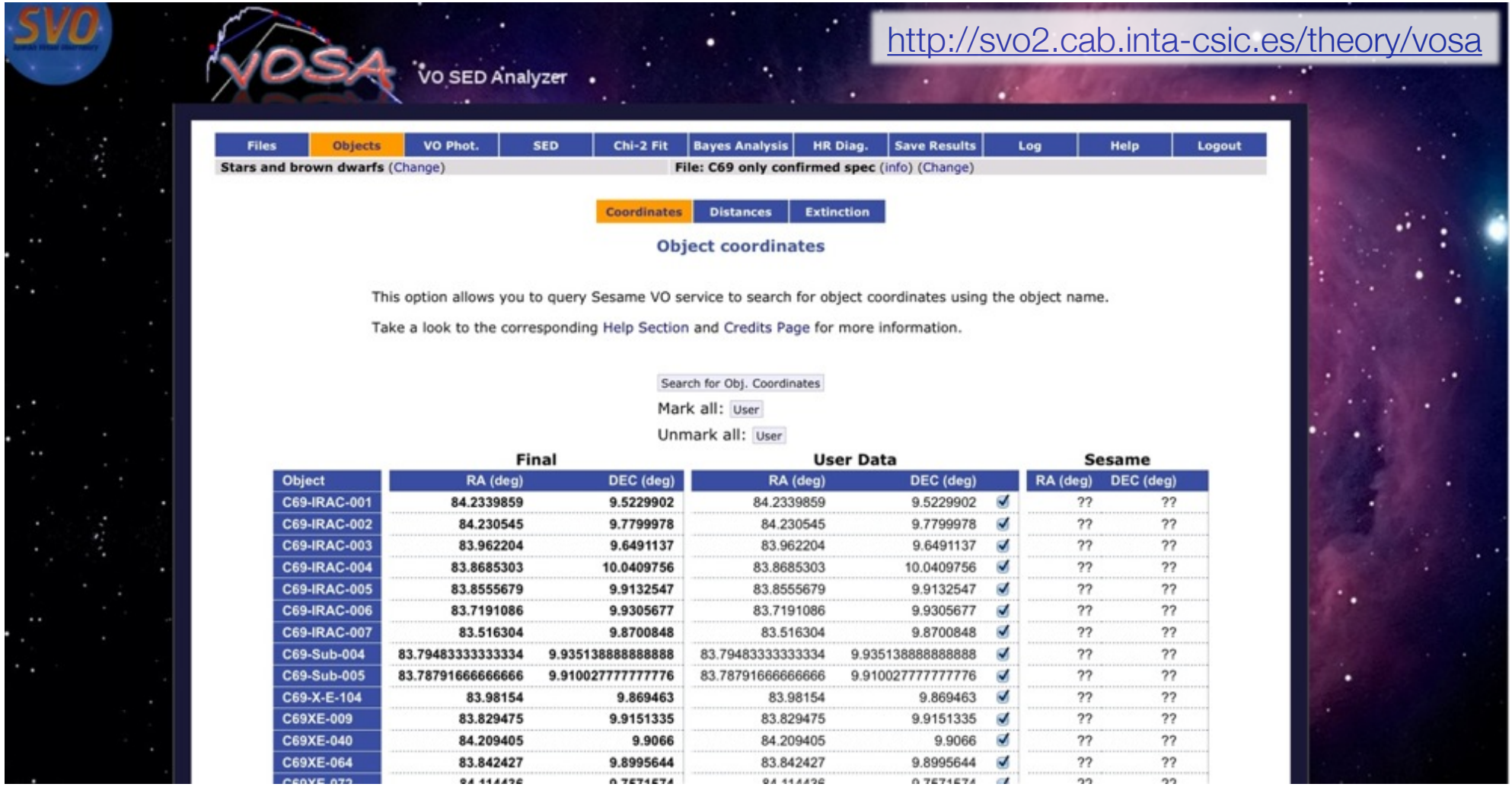
VOSA 2: the new generation



~200 regular users, cited in ~ 50 papers

Bayo et al. (2008, 2014a subm.)

VOSA 2: the new generation

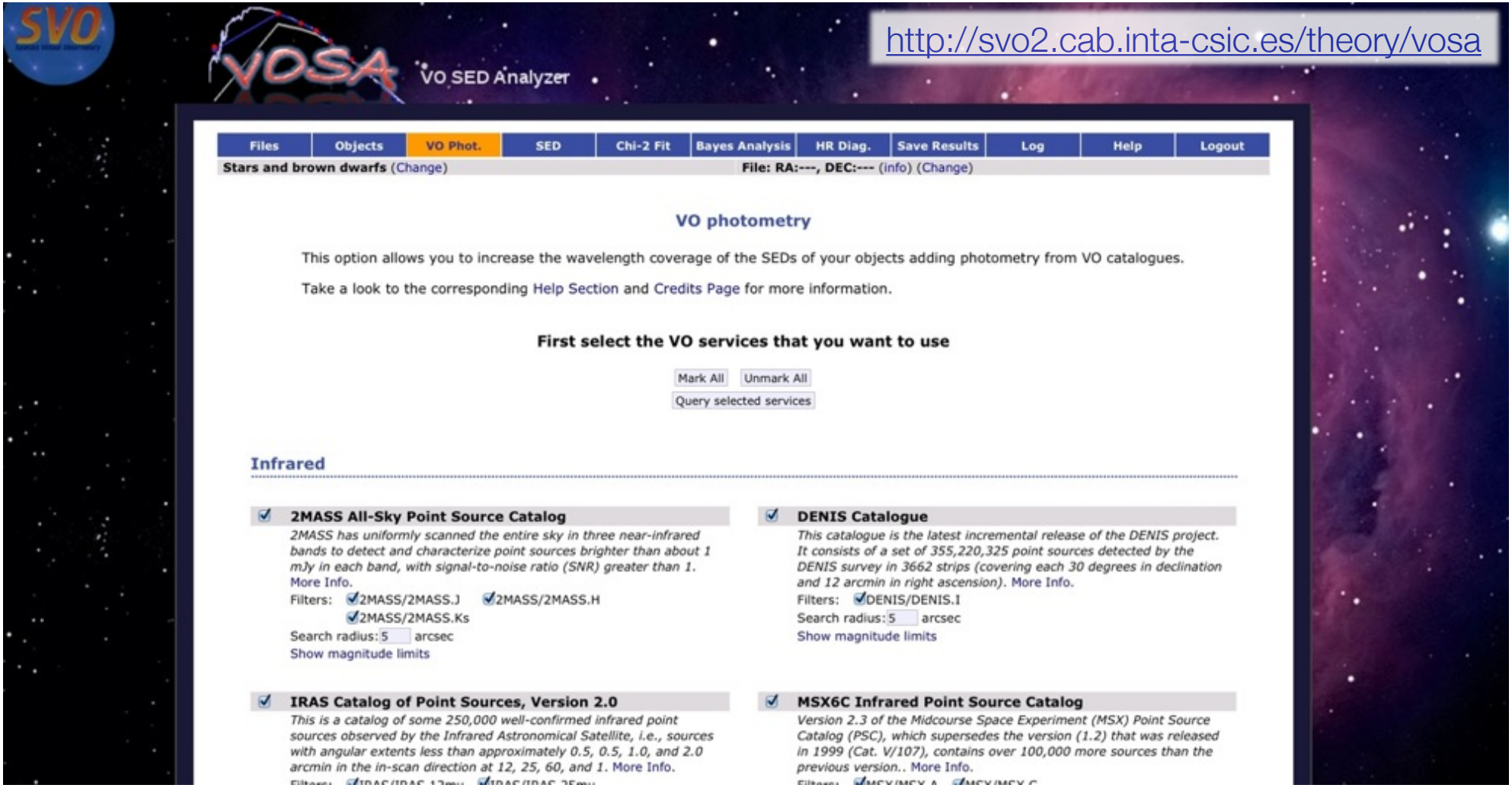


	Final		User Data			Sesame	
Object	RA (deg)	DEC (deg)	RA (deg)	DEC (deg)		RA (deg)	DEC (deg)
C69-IRAC-001	84.2339859	9.5229902	84.2339859	9.5229902	☑	??	??
C69-IRAC-002	84.230545	9.7799978	84.230545	9.7799978	☑	??	??
C69-IRAC-003	83.962204	9.6491137	83.962204	9.6491137	☑	??	??
C69-IRAC-004	83.8685303	10.0409756	83.8685303	10.0409756	☑	??	??
C69-IRAC-005	83.8555679	9.9132547	83.8555679	9.9132547	☑	??	??
C69-IRAC-006	83.7191086	9.9305677	83.7191086	9.9305677	☑	??	??
C69-IRAC-007	83.516304	9.8700848	83.516304	9.8700848	☑	??	??
C69-Sub-004	83.79483333333334	9.935138888888888	83.79483333333334	9.935138888888888	☑	??	??
C69-Sub-005	83.78791666666666	9.910027777777776	83.78791666666666	9.910027777777776	☑	??	??
C69-X-E-104	83.98154	9.869463	83.98154	9.869463	☑	??	??
C69XE-009	83.829475	9.9151335	83.829475	9.9151335	☑	??	??
C69XE-040	84.209405	9.9066	84.209405	9.9066	☑	??	??
C69XE-064	83.842427	9.8995644	83.842427	9.8995644	☑	??	??

~200 regular users, cited in ~ 50 papers

Bayo et al. (2008, 2014a subm.)

VOSA 2: the new generation



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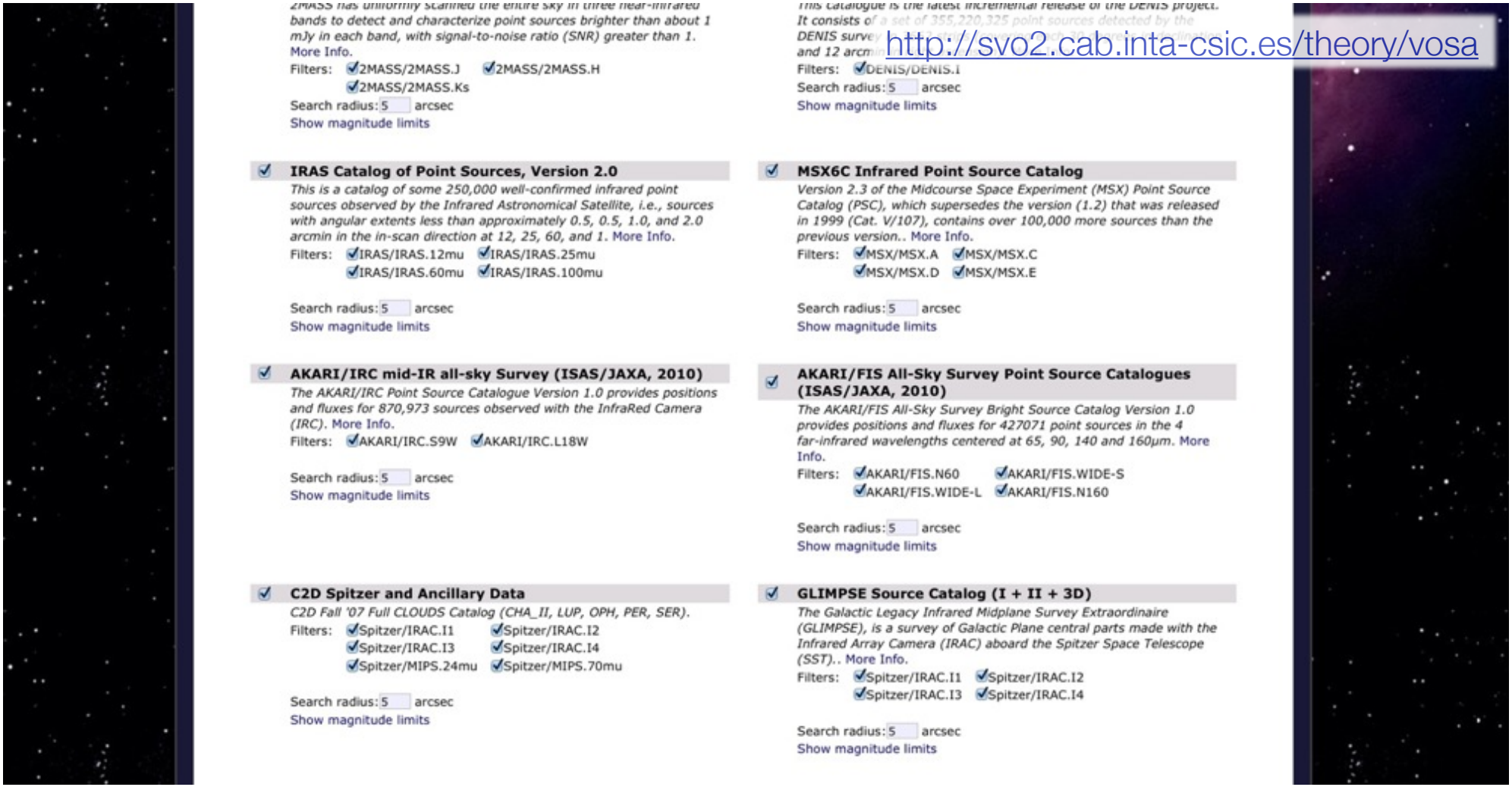
Bayo et al. (2008, 2014a subm.)

VOSA 2: the new generation

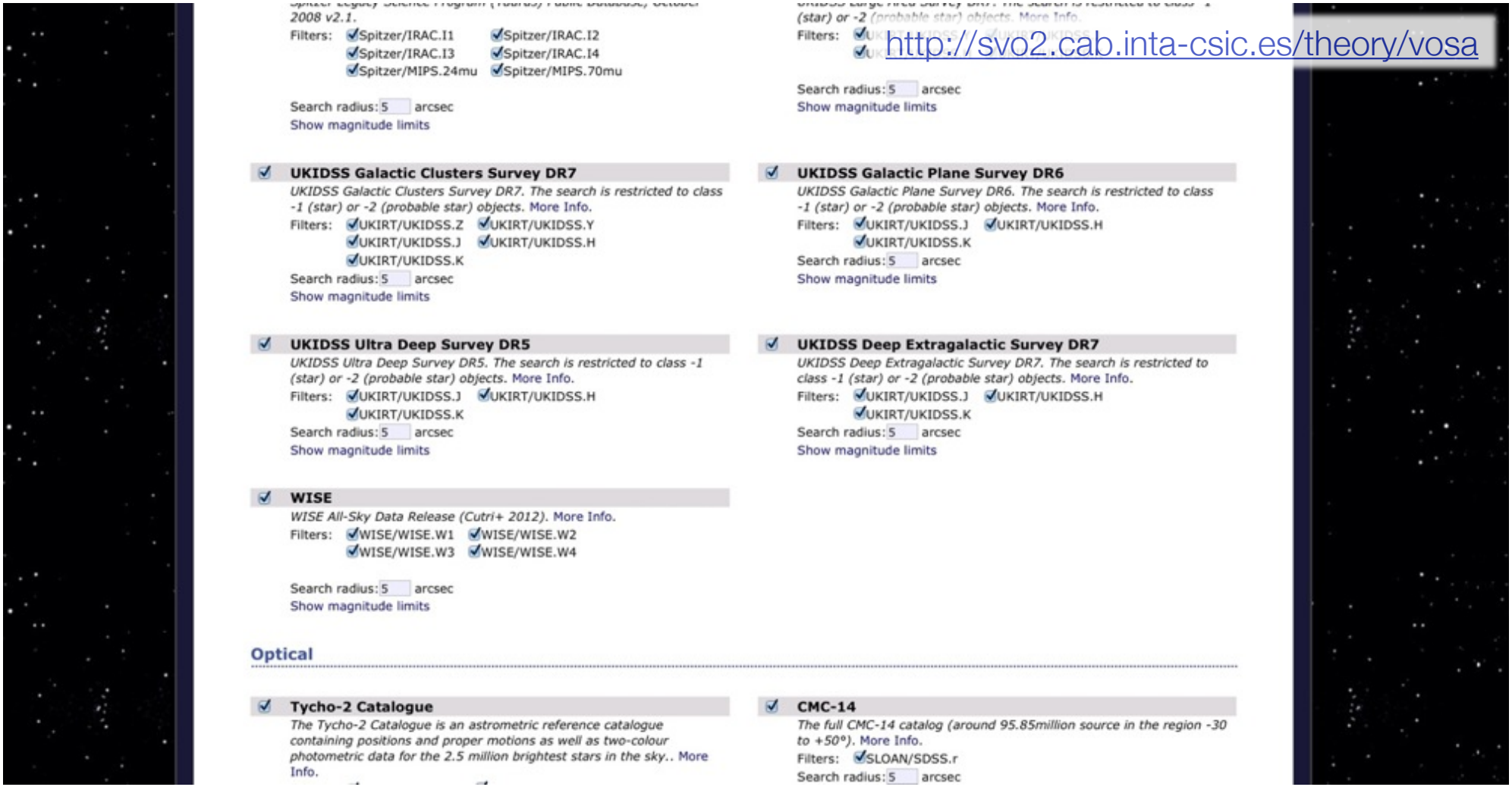


http://svo2.cab.inta-csic.es/theory/vosa

~200 regular users, cited in ~ 50 papers

Bayo et al. (2008, 2014a subm.)

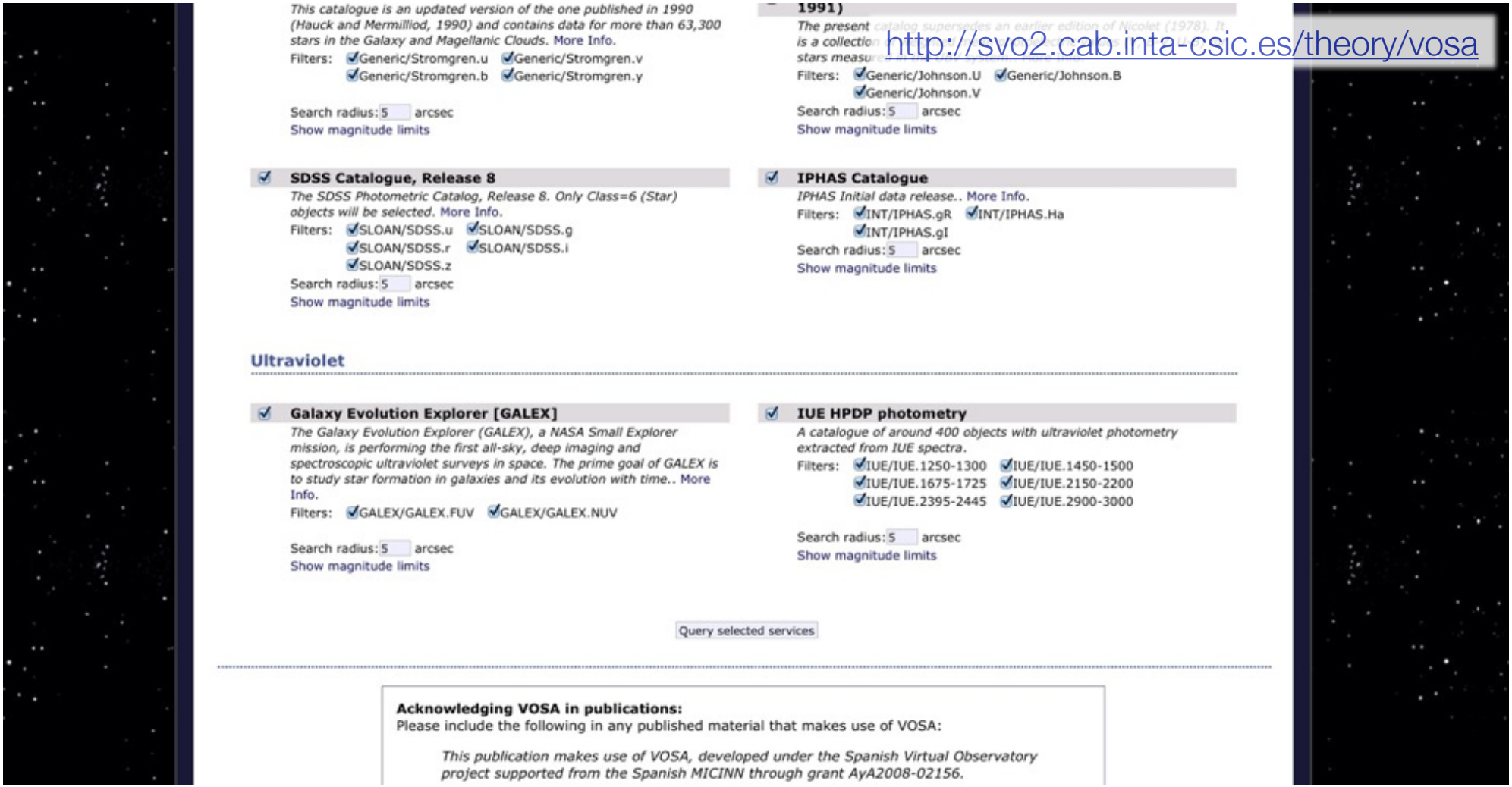
VOSA 2: the new generation



~200 regular users, cited in ~ 50 papers

Bayo et al. (2008, 2014a subm.)

VOSA 2: the new generation



http://svo2.cab.inta-csic.es/theory/vosa

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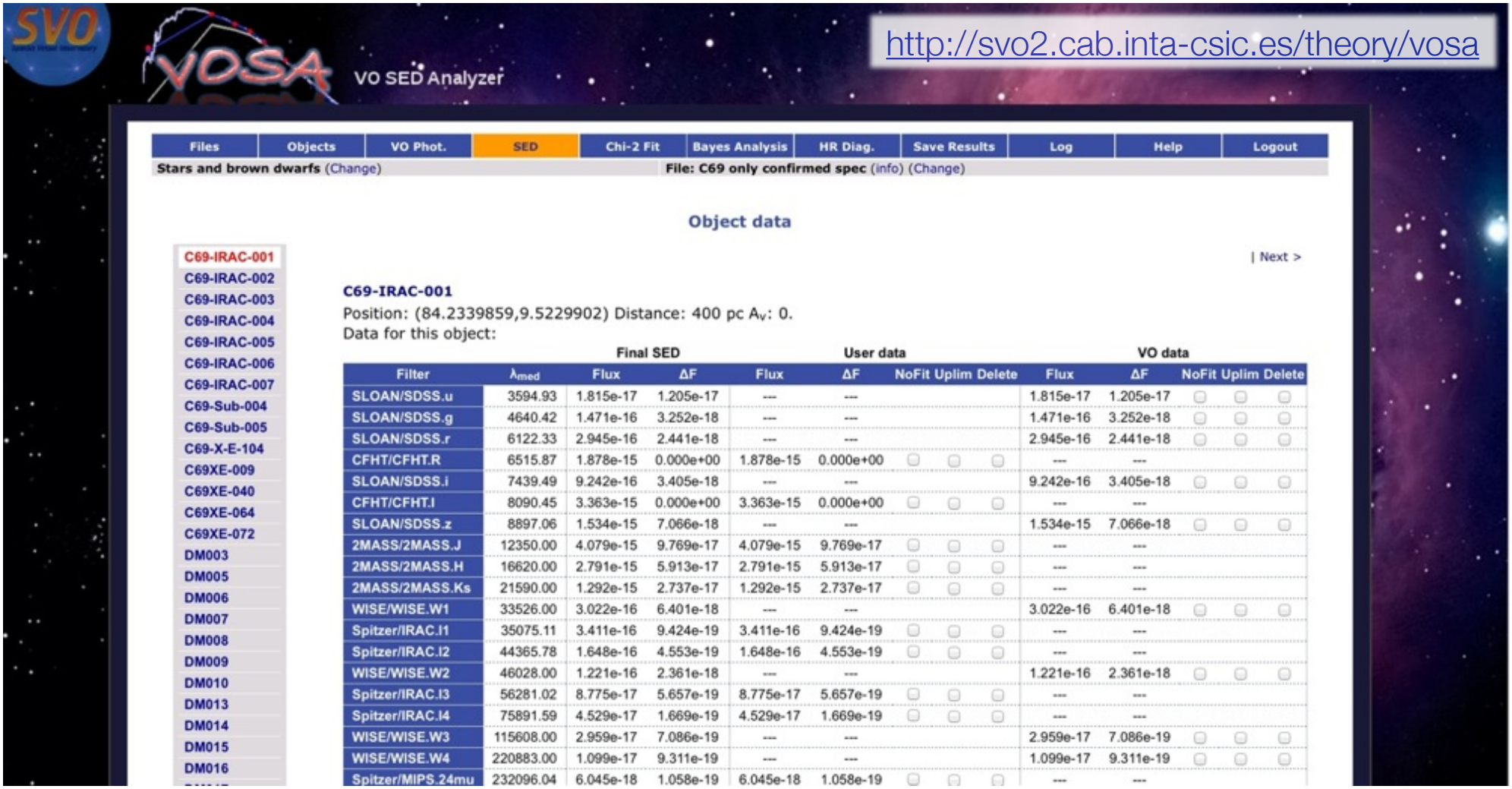
Bayo et al. (2008, 2014a subm.)

VOSA 2: the new generation



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SLOAN/SDSS.u	3594.93	1.815e-17	1.205e-17	---	---				1.815e-17	1.205e-17			
SLOAN/SDSS.g	4640.42	1.471e-16	3.252e-18	---	---				1.471e-16	3.252e-18			
SLOAN/SDSS.r	6122.33	2.945e-16	2.441e-18	---	---				2.945e-16	2.441e-18			
CFHT/CFHT.R	6515.87	1.878e-15	0.000e+00	1.878e-15	0.000e+00				---	---			
SLOAN/SDSS.i	7439.49	9.242e-16	3.405e-18	---	---				9.242e-16	3.405e-18			
CFHT/CFHT.I	8090.45	3.363e-15	0.000e+00	3.363e-15	0.000e+00				---	---			
SLOAN/SDSS.z	8897.06	1.534e-15	7.066e-18	---	---				1.534e-15	7.066e-18			
2MASS/2MASS.J	12350.00	4.079e-15	9.769e-17	4.079e-15	9.769e-17				---	---			
2MASS/2MASS.H	16620.00	2.791e-15	5.913e-17	2.791e-15	5.913e-17				---	---			
2MASS/2MASS.Ks	21590.00	1.292e-15	2.737e-17	1.292e-15	2.737e-17				---	---			
WISE/WISE.W1	33526.00	3.022e-16	6.401e-18	---	---				3.022e-16	6.401e-18			
Spitzer/IRAC.I1	35075.11	3.411e-16	9.424e-19	3.411e-16	9.424e-19				---	---			
Spitzer/IRAC.I2	44365.78	1.648e-16	4.553e-19	1.648e-16	4.553e-19				---	---			
WISE/WISE.W2	46028.00	1.221e-16	2.361e-18	---	---				1.221e-16	2.361e-18			
Spitzer/IRAC.I3	56281.02	8.775e-17	5.657e-19	8.775e-17	5.657e-19				---	---			
Spitzer/IRAC.I4	75891.59	4.529e-17	1.669e-19	4.529e-17	1.669e-19				---	---			
WISE/WISE.W3	115608.00	2.959e-17	7.086e-19	---	---				2.959e-17	7.086e-19			
WISE/WISE.W4	220883.00	1.099e-17	9.311e-19	---	---				1.099e-17	9.311e-19			
Spitzer/MIPS.24mu	232096.04	6.045e-18	1.058e-19	6.045e-18	1.058e-19				---	---			

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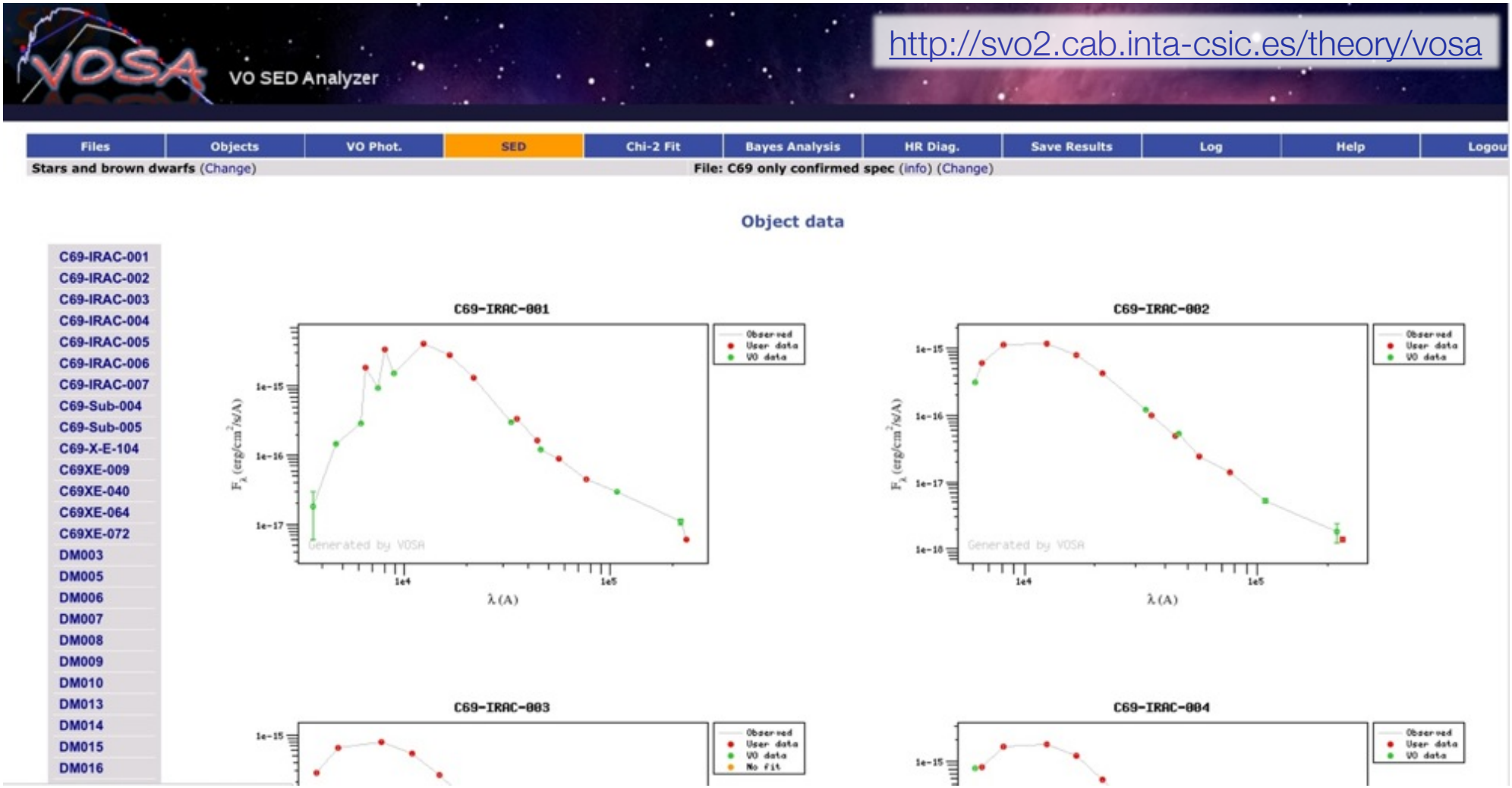
VOSA 2: the new generation



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